PHIL Accelerator at LAL - Diagnostic status

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J. Brossard#, F. Blot, S. Cavalier, A. Gonnin, M. Joré, P. Lepercq,
S. Letourneur, B. Mercier, H. Monard, C. Prevost, R. Roux, A. Variola,
LAL-CNRS-IN2P3/ Université Paris-Sud XI, bâtiment 200, 91898 Orsay, France.

Abstract

The "Photo-Injector at LAL" (PHIL : http://phil.lal.in2p3.fr/) is a new electron beam accelerator at LAL. This accelerator is dedicated to test and characterise electrons photo-guns and high-frequency structures for futur accelerator projects (like the next generation lepton colliders, CLIC, ILC). This machine has been designed to produce low energy (E<10 MeV), small emittance (ε # 10 π.mm.mrad), high current (charge # 2 nC/bunch) electrons bunch at low repetition frequency (ν_{rep}<10Hz) [1]. The first beam has been obtained on the 4th of november 2009. This paper will describe the current status and the futurs developpements of the diagnotics devices on this machine.

DESCRIPTION OF THE PHIL ACCELERATOR

PHIL is currently a 6 meters long accelerator with 2 diagnostics beam lines (see Figure 3). The direct beam line is mainly devoted to 2D transverse emittance and bunch length measurement. The deviate beam line is devoted to the mean and dispersion energy beam measurement. The injection in the deviated line is performed by a Tesla Test Facility (TTF) injector dipole.

The direct beam line is equipped with :

– 2 Beam Position Monitor (BPM).
– 1 phosphorescent transverse beam profile monitor.
– 1 Faraday Cup (FC).

One of the BPM is of the "button electrode" type, the other is of "re-entrant cavity" type. The beam profile monitor is a phosphorescent screen oriented at 45° from the beam axis. The screen is a cerium-doped yttrium:aluminium:garnet (YAG:Ce) crystal scintillator (300 μm thickness, 40 mm of diameter). Images have already been acquired on this first screen (located at 1925 mm from the photo-cathode). These preliminary measurements have shown that a millimeters size beam in both horizontal and vertical planes is already reachable (see Figure 2). The vertical and horizontal beam sizes are estimated using N differents images, after drak current substration (see Figure 1).

The FC is located at the end of the direct beam line.

The machine is also equipped with a false photo-cathode test pattern used to check the laser spot size and the position on the real photo-cathode.

Currently, the deviate beam line is only equipped with one Faraday Cup.

brossard@lal.in2p3.fr

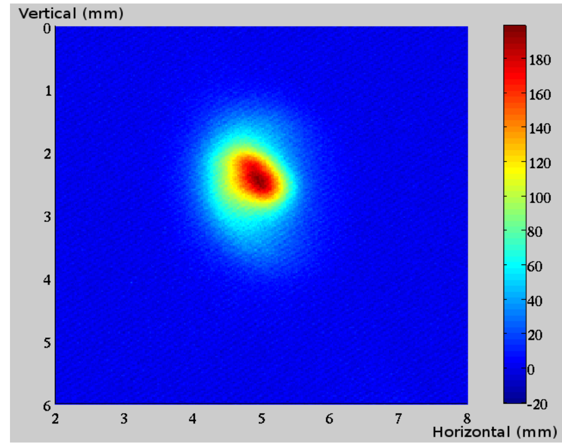

Figure 2: example of average transverse beam profile obtained at the first YAG:Ce screen station (1925 mm from the photocathode) using 10 images. For each images, the dark current has been substracted but not the jitter position.

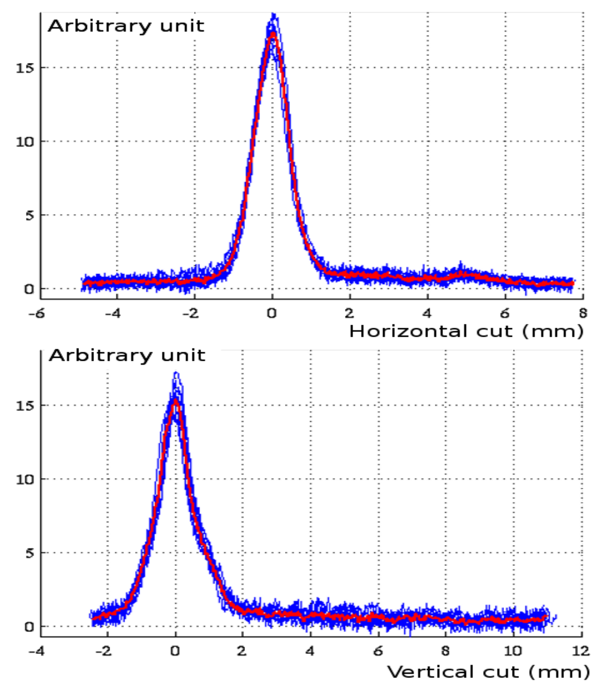

Figure 1: CCD intensity signal projected on horizontal and vertical axis (for 10 images) used for beam size estimation. The red curve is the average cut. On theses blues curves, the dark current and the jitter position have been substracted.

TRANSVERSE BEAM EMITTANCE, SIZE AND POSITION MEASUREMENTS

In 2010, three others phosphorescent YAG:Ce screen monitors will be installed on PHIL. The first one will be mounted at the entrance of the dipole. It will give important informations on the beam behaviour just before the dipole, which will be used to correctly prepare the beam for mean and energy spread measurement on the deviate line. It will also be used for 2D transverse emittance measurement using Kapchinskij-Vladimirskij equations and/or slit and/or pepper pot technique. The two others screens will be placed at the end of each beam lines, just before the Faraday cups. The one located on the direct beam line will be used to precisely define and control the transverse beam size and position for futurs users. The one located on the deviated beam line will be place just after the variable slit and will be used for cross-checked the mean and dispersion energy measurements done with the Faraday cup.

Each phosphorescent screen is associated with a versatile optical system (made of one or more achromatic lens) and a Giga-ethernet CCD camera (2 with 1/3” sensor format with 7.4 µm pixel size and 2 with 1/2” sensor format with 4.65 µm pixel size). The CCD dynamic is coded on 8 bit. In front of each camera a remote control optical density wheel is mounted in order to avoid pixel saturation during measurement.

CHARGE MEASUREMENT

For the charge measurement and the losses estimation, 2 Integrating Current Transformer (ICT) along the accelerator will be installed. One will be place at the exit of the photo-injector in order to characterise the beam charge at the beginning of the line, and one at the end of the direct beam line just before the BPM and the YAG:Ce screen. This will enable us to performed a beam charge, beam size and beam position measurement at the same time and location for the same bunch.

ENERGY SPREAD MEASUREMENT

The injector TTF dipole is a 60°[1] sector dipole with face angle of 18.24° [2]. The focal length L_D computed with the following formula

$$L_D = \frac{\rho * (c\alpha + \tan(u_1) * s\alpha)}{s\alpha - (\tan(u_1) + \tan(u_2)) * c\alpha - \tan(u_1) * \tan(u_2) * s\alpha}$$

where

$s\alpha = \sin(\alpha)$ and $c\alpha = \cos(\alpha)$

with ρ=700 mm, α=60° and u_1=u_2=18.24° is L_D=1242.70 mm. This distance is calculated from the center of the exit face dipole. A precise energy spread measurement require to inject - in the dipole - a beam without angular divergence and to monitor the horizontal beam size at a distance L_D after the dipole. In the current status, the girder supporting the elements of the deviate beam line is too short to performe such measurement. Thus, in the first commissioning part, the slit and the YAG:Ce screen monitor will be placed at a shorter distance, and energy spread estimation will be evaluated by comparison between measurement and the PARMELA software simulations [3]. The accuracy level of the energy spread measurement is – in this configuration - not yet established, and more numerical analysis are required.

[1] The deviation is performed in the horizontal plan.

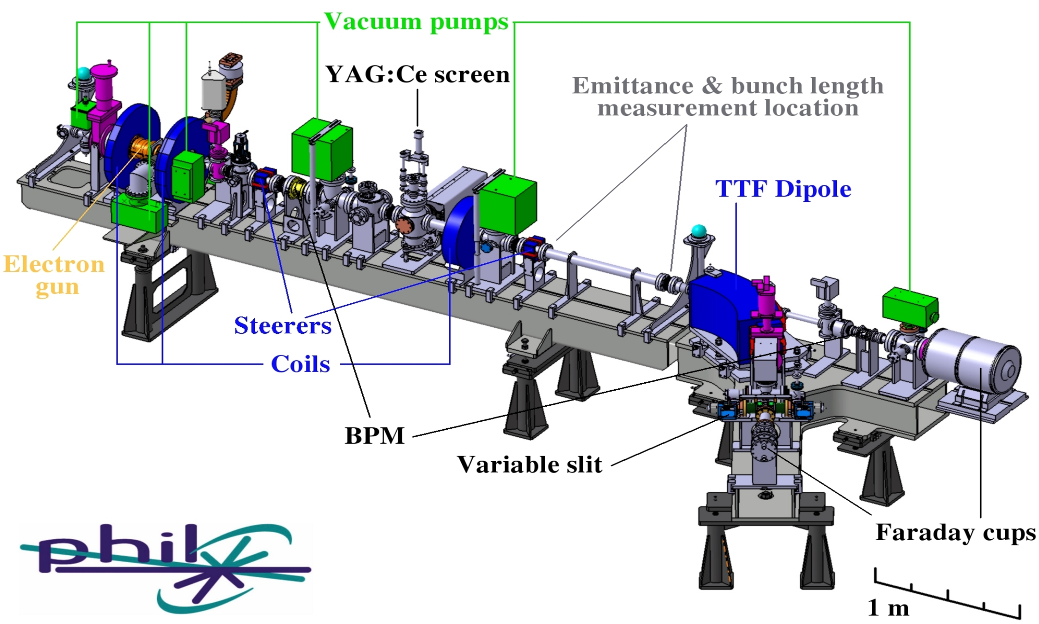

Figure 3: current and some futurs diagnostics on PHIL.

BUNCH LENGTH MEASUREMENT

A Cerenkov detector will be installed for bunch length measurement using a streak camera. The used streak camera is currently located in the laser room, wich is 17 meters away from the machine. This quite long distance associated with the streak camera type used migth be a limitation for the minimum signal level that can be detected. This device and the optical transport system have to be accurately studyed in order to determine the faisability and the accuracy of such measurement.

CONCLUSION

The "PHoto-Injector at LAL" (PHIL : http://phil.lal.in2p3.fr/) is a new electrons beam accelerator at LAL. The first electron beam generated with this machine is very recent (4th november 2009) and first beam measurements are currently used to test, calibrate and cross-checked existing diagnostics elements (beam position monitor, transverse beam profile monitor, charge monitor). Futurs diagnostics elements (energy spread, ICT, 2D transverse emittance, bunch length) are under study and we hope a complete installation of the news diagnotics for the end of 2010.

REFERENCES

[1] R. Roux & al., "PHIL : a test beamline at LAL", Proceedings of EPAC 2008, Genoa, Italy.
[2] R. Chehab, "Progress in the Study and Construction of the TESLA Test Facility Injector", Particle Acceleratopr Conference, Dallas, 1995.
[3] PARMELA software, from Los Alamos National Laboratory.